THE NASA-ISRO SAR (NISAR) MISSION DUAL-BAND RADAR INSTRUMENT PRELIMINARY DESIGN

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Outline of Talk

Previous talks and conference papers have focused primarily on L-band technical capabilities, designs, and science objectives

In this talk, we will focus on the joint L- and S-band aspects of the mission

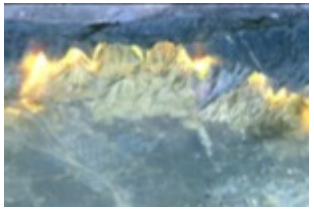
- NISAR Mission Overview
- Current Development Status
- ISRO Science and Application Objectives
- Joint L+S-band observation plan
- Airborne L+S-band system description
- Coordination of the L- and S-band instruments
- Conclusion

NISAR Mission Overview

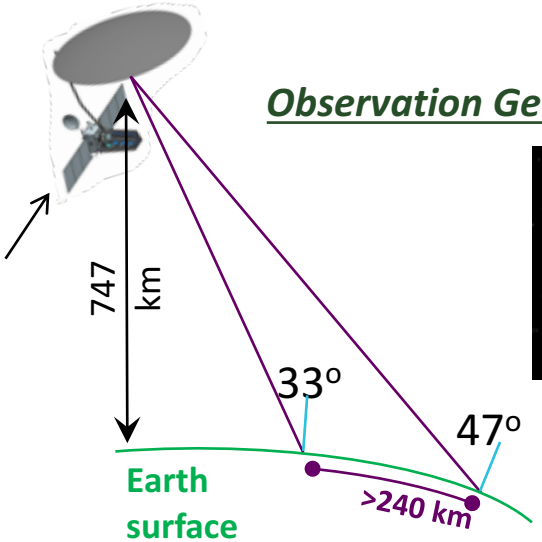
NISAR Characteristic:	Would Enable:
L-band (24 cm wavelength)	Low temporal decorrelation and foliage penetration
S-band (12 cm wavelength)	Sensitivity to light vegetation
SweepSAR technique with Imaging Swath > 240 km	Global data collection
Polarimetry (Single/Dual/Quad)	Surface characterization and biomass estimation
12-day exact repeat	Rapid Sampling
3 – 10 meters mode-dependent SAR resolution	Small-scale observations
3 years science operations (5 years consumables)	Time-series analysis
Pointing control < 273 arcseconds	Deformation interferometry
Orbit control < 500 meters	Deformation interferometry
> 30% observation duty cycle	Complete land/ice coverage
Left/Right pointing capability	Polar coverage, north and south

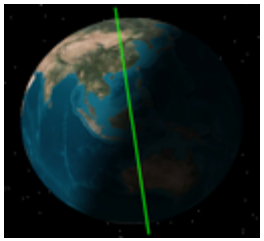
NISAR Will Uniquely Capture the Earth in Motion






Observation Geometry





NISAR Radar Modes

		Science			Performance			
Config. ID	Old Mode #	Primary Science Target	Freq Band	Polarization	BW (MHz)	PRF (Hz)	PW [μ sec]	Swath [km]
128	**L1**	Background Land	L	DP HH/HV	20+5	1650	25	242
129		Background Land Soil Moisture	L	QQ	20+5	1650	25	242
130		Background Land Soil Moisture Hi Pwr	L	QQ	20+5	1650	20	242
131	**L2**	Land Ice	L	SP HH	80	1650	40	121
132		Land Ice Low Res	L	SP HH	40+5	1650	45	242
133		Low Data Rate Study Mode SinglePol	L	SP HH	20+5	1650	25	242
134	**L3**	Sea Ice Dynamics	L	SP VV	5	1600	25	242
135		Open Ocean	L	QD HH/VV	5+5	1650	20	242
136	**L4**	India Land Characterization	L	DP VV/VH	20+5	1650	25	242
137	**L5**	Urban Areas, Himalayas	L	DP HH/HV	40+5	1650	45	242
138		Urban Areas, Himalayas SM	L	QQ	40+5	1650	45	242
139		Urban Areas, Himalayas SM Hi Pwr	L	QQ	40+5	1650	40	242
140	**L6**	US Agriculture, India Agriculture	L	QP HH/HV/VH/VV	40+5	1600*	45	242
141	**LX**	US Agriculture, India Agriculture Low Res	L	QP HH/HV/VH/VV	20+5	1600*	45	242
142	**L7**	Experimental CP mode	L	CP RH/RV	20+20	1650	40	242
143	**L8**	Experimental QQ mode	L	QQ	20+20	1650	20	242
144	**L9**	Experimental SP mode	L	SP HH	80	1650	20	242
145		ISRO Ice/sea-ice	L	DP VV/VH	5	1650	25	242
146		ISRO Ice/sea-ice - alternate	L	QD HH/VV	5	1650	25	242
64	**S1**	Solid Earth/Ice/Veg/Coast/Bathym	S	Quasi-Quad	37.5	2200	10+10	244
65	**S2**	Ecosystem/Coastal Ocean/Cryosphere	S	DP HH/HV	10	2200	25	244
66	**S3**	Agriculture/Sea Ice	S	CP RH/RV	25	2200	25	244
67	**S4**	Glacial Ice-High Res	S	CP RH/RV	37.5	2200	25	244
68	**SX**	New mode	S	DP HH/HV	37.5	2200	25	244
69	**S5**	Deformation	S	SP HH (or SP VV)	25	2200	25	244
70	**S6**	Deformation-Max Res	S	SP HH (or SP VV)	75	2200	25	244

NISAR Joint Radar Modes

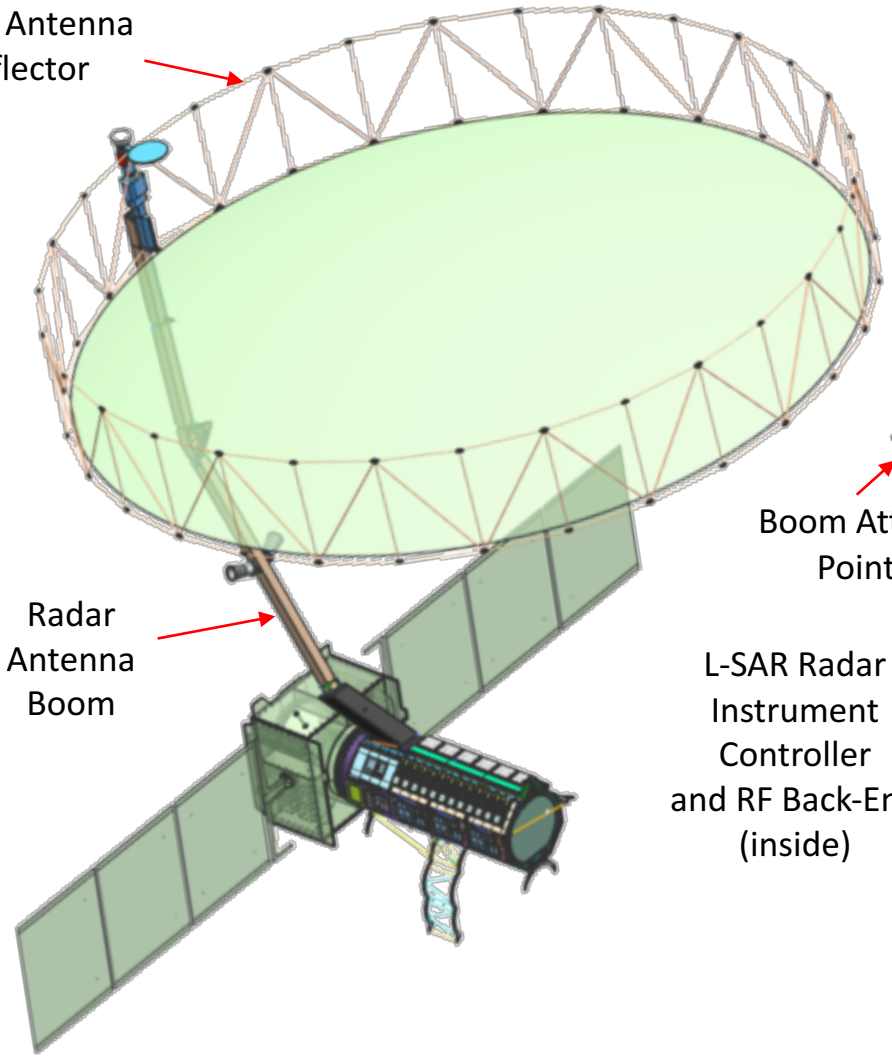
		Science			Performance			
Config. ID	Old Mode #	Primary Science Target	Freq Band	Polarization	BW (MHz)	PRF (Hz)	PW [μ sec]	Swath [km]
192	**L1+S3**	Systematic Coverage	L+S	DP HH/HV CP RH/RV	20+5 25	1910^	25 25	242 244
193	**L1+S4**	Systematic Coverage & Deformation	L+S	DP HH/HV DP HH/HV	20+5 37.5	1910^	25 25	242 244
194	**L1+S5**	Coastal-Mudbank (wet soil ????)	L+S	DP HH/HV SP HH (or SP VV)	20+5 25	1910^	25 25	242 244
195	**L3+S2**	Ocean	L+S	SP VV DP VV/VH	5 10	1910^	25 25	242 244
196	**L4+S3**	Sea Ice Types	L+S	L: DP VV/VH S: CP RH/RV	20+5 25	1910^	25^ 25	242 244
197	**L5+S4**	Glacial Ice-Himalayas	L+S	L: DP HH/HV S: CP/RH/RV	40+5 37.5	1910^	45^ 25	242 244
198	**L5+S6**	High-Res Deformation(Disaster/Urgent Response)	L+S	L: DP HH/HV S: SP HH (or SP VV)	40+5 75	1910^	45^ 25	242 244
199	**L6+S3**	India Agriculture	L+S	L: QP HH/HV/VH/VV S: CP RH/RV	40+5 25	1550*^ 3100	45^ 10'	242 244
200	**L6+SX**	Coastal - Land	L+S	L: QP HH/HV/VH/VV S: DP HH/HV	40+5 37.5	1550*^ 3100	45^ 10'	242 244
201	**LX+S3**	Coastal - X	L+S	L: QP HH/HV/VH/VV S: CP HH/HV	20+5 25	1550*^ 3100	45^ 10'	242 244
202	**LX+SX**	Coastal - X	L+S	L: QP HH/HV/VH/VV S: DP HH/HV	20+5	1550*^ 3100	45^ 10'	242 244
203	**L?+S3**	ISRO Ice/sea-ice	L+S	DP VV/VH CP RH/RV	5 25	1910^	25 25	242 244
204	**L?+S2**	ISRO Ice/sea-ice - Jjoint Alternate	L+S	DP VV/VH DP VV/VH	5 10	1910^	25 25	242 244

NISAR Science Observing/Operations Modes
Blanket Land and Ice Coverage Every 12 Days

- Observation strategy employs a subset of possible modes

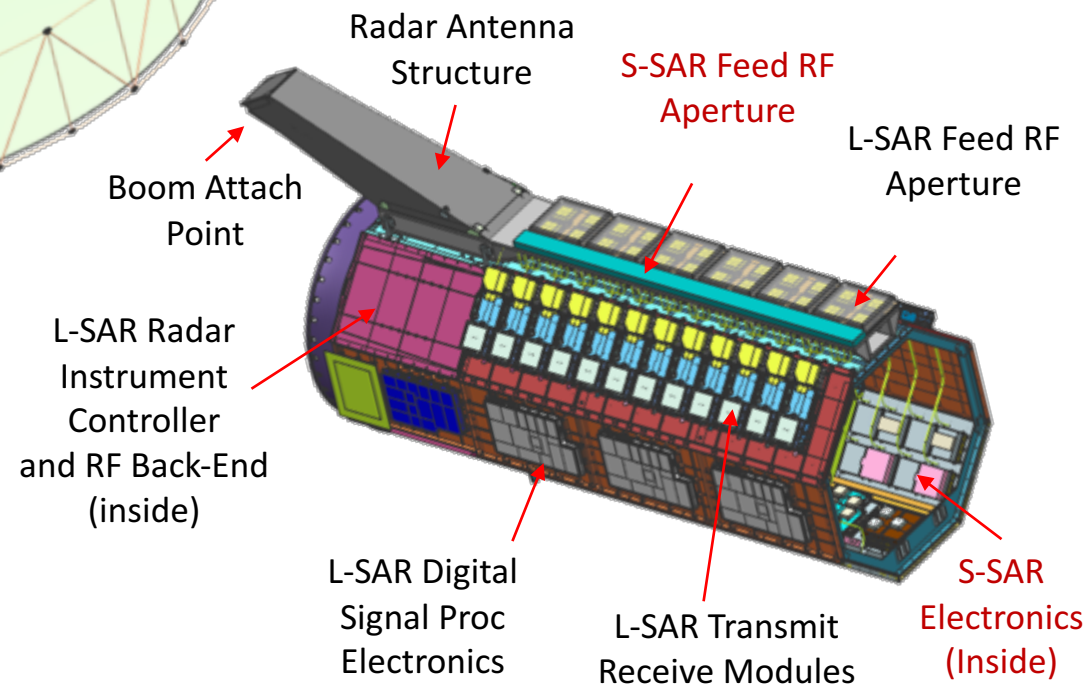
Observation Strategy	L-band		S-band		Culling Approach	
Science Target	**Mode⁺**	**Resolution**	**Mode**	**Resol.**	Sampling	Desc Asc
Background Land	DP HH/HV	12 m x 8 m			cull by lat	
Land Ice	SP HH	3 m x 8 m			cull by lat	
Sea Ice Dynamics	SP VV	48 m x 8 m			s = 1 p	
Urban Areas		6 m x 8 m			s = 1 p	
US Agriculture	QP HH/HV VV/VH				s = 1 p	
Himalayas			CP RH/RV		s = 1 p	
India Agriculture					s = 1 p	
India Coastal Ocean			DP HH/HV or VV/VH		s = 1 p	
Sea Ice Types	DP VV/VH				s = 3 p	

NISAR Instrument Overview



Instrument Subsystems:

- L-Band SAR (JPL)
- S-Band SAR (ISRO)
- Instrument Structure (JPL)
- Radar Antenna (JPL)



Instrument Structure also houses GPS unit and Solid State Recorder

Progress in Development Phase C
L-band SAR Hardware (1/2)


EM Waveform Generator

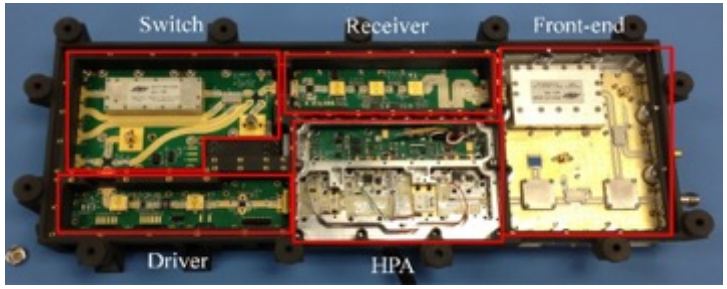

EM Up Converter Driver


EM Frequency Synthesizer

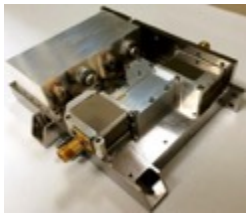

EM RBE-PCU

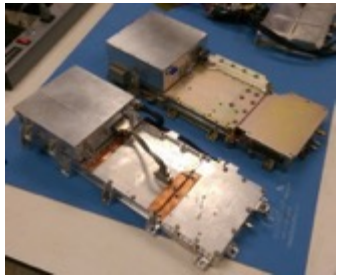

EM RBE Stack


EM TRM-ESS



TRM Pathfinder EM

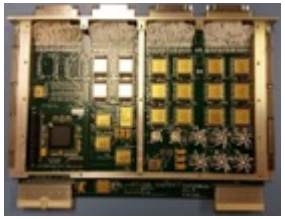

EM Front-End Subassembly (FES)


Prototype and Pathfinder TRMs

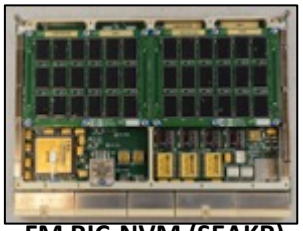

EM RIC-CTB


EM RIC-SIF


RIC- RAD750 Qual Model

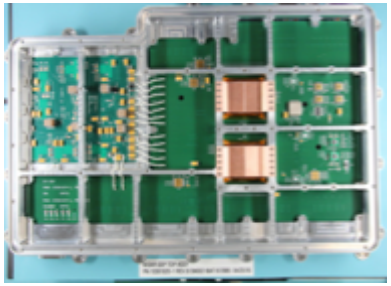

EM RIC-HKT


EM RIC-PCU


FM RIC-NVM (SEAKR)

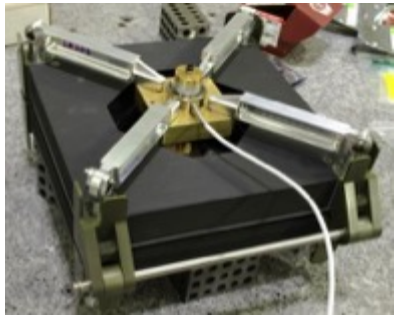
Digital Signal Processor


EM QFSP


EM SSP

Progress in Development Phase C
L-band SAR Hardware (2/2)

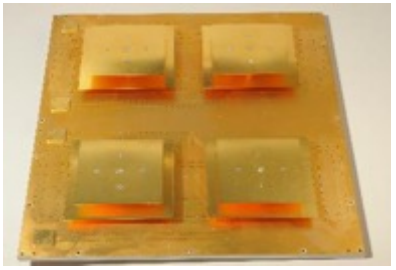
Boom and Hinge Development Hardware



10” Development Boom Stability Test

7” Prototype Boom/Hinge in fabrication

L-FRAP Feed Tile Development Hardware

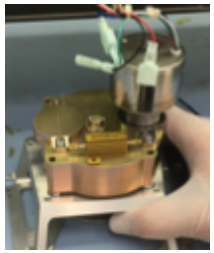


Feed Tile EM (without radome)

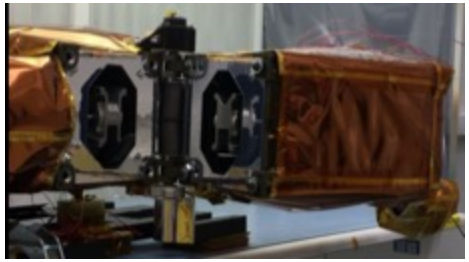
Feed Array EM in Test

Hinge Deploy & Latching H/W

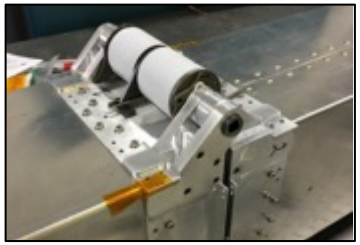
PT Spring Assemblies



Boom Actuator PT



Prototype 7” Spring/Damper Deploy Test



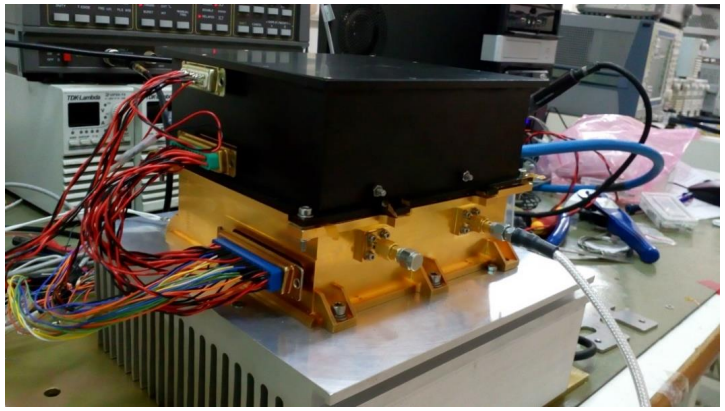
Hinge Spring Cartridge Torque Test

Boom Harness Torque Test

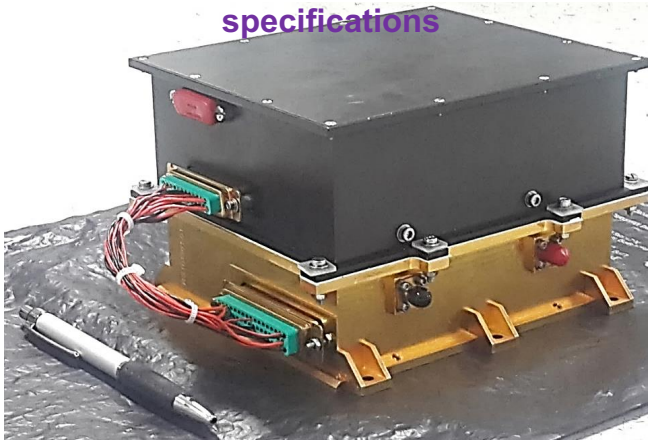
Progress in Development Phase C
S-Band Hardware

RF Hardware Development

TRiM Under Test

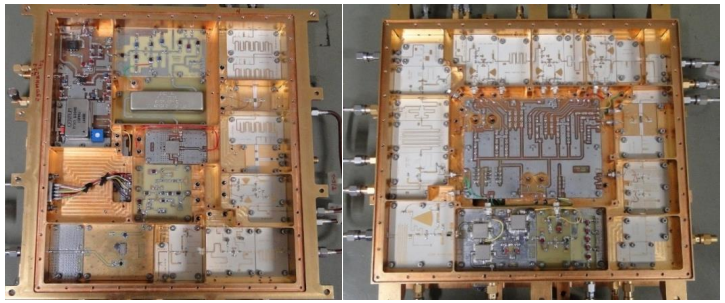


TRiM meets all electrical specifications



- Performance verification over temperature
- 30 nos. of DVM & 64 nos. of FM TRiMs will be done by Indian Industries (Fabrication, assembly and Testing)

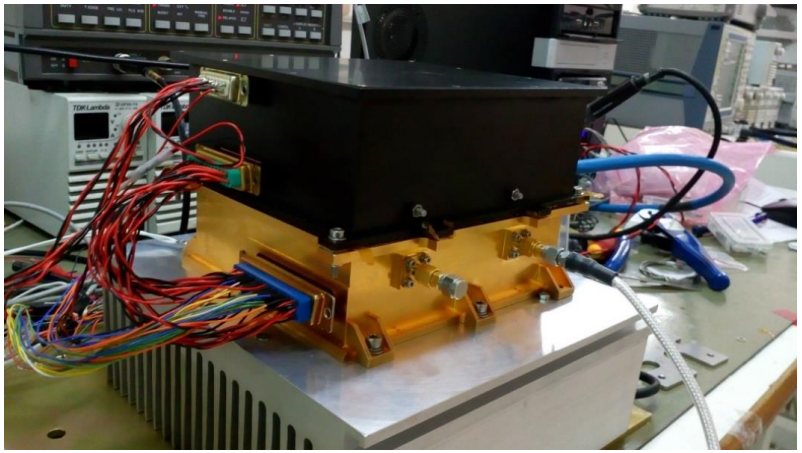
SynOT
FM - Layout modification in progress



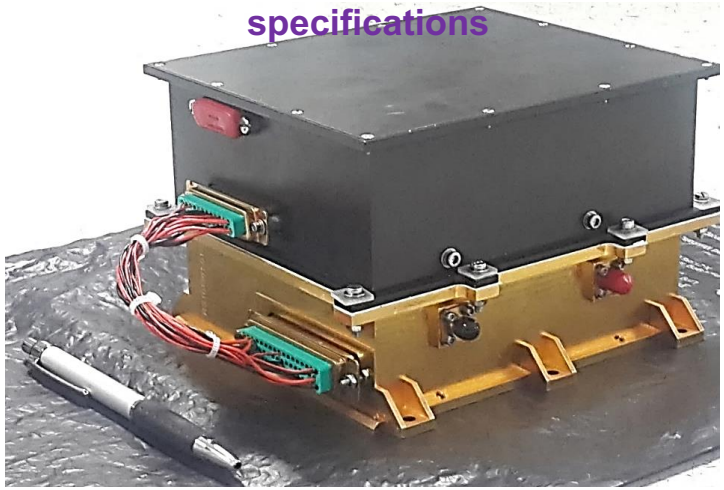
- DVM Package assembly is in progress
- Delivery : July, 2017.

Progress in Development Phase C
ISRO S-Band RF Hardware

TRiM Under Test



TRiM meets all electrical specifications



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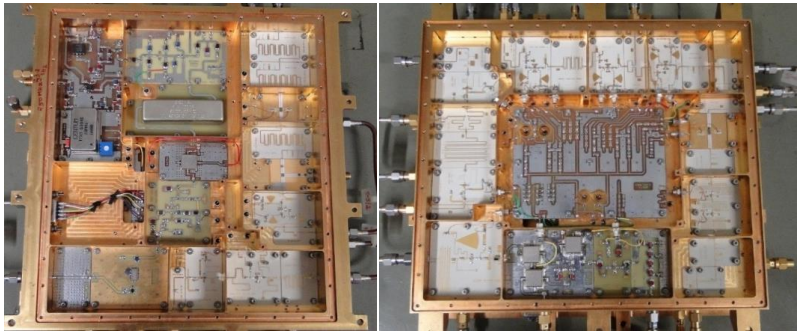

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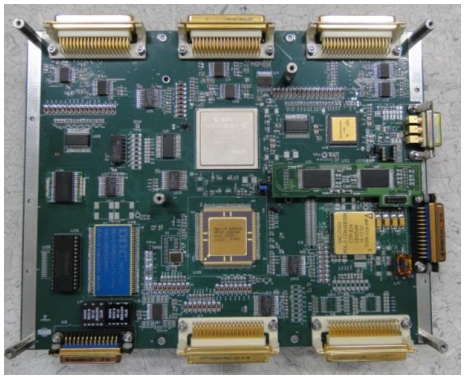
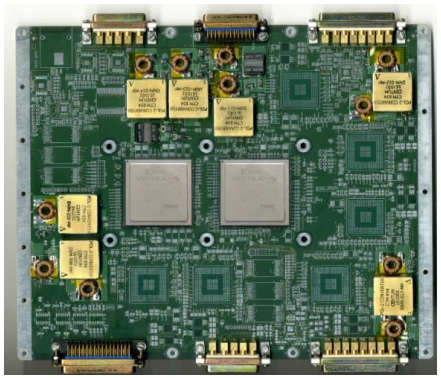
Front-end Radiating Aperture
S-band Development and Joint L+S compatibility

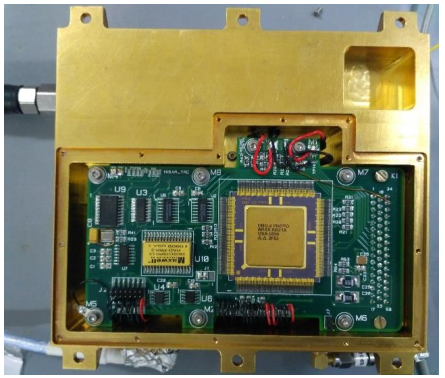
ISRO S-band Hardware and Configuration



DVM PLCG (Ver-4)

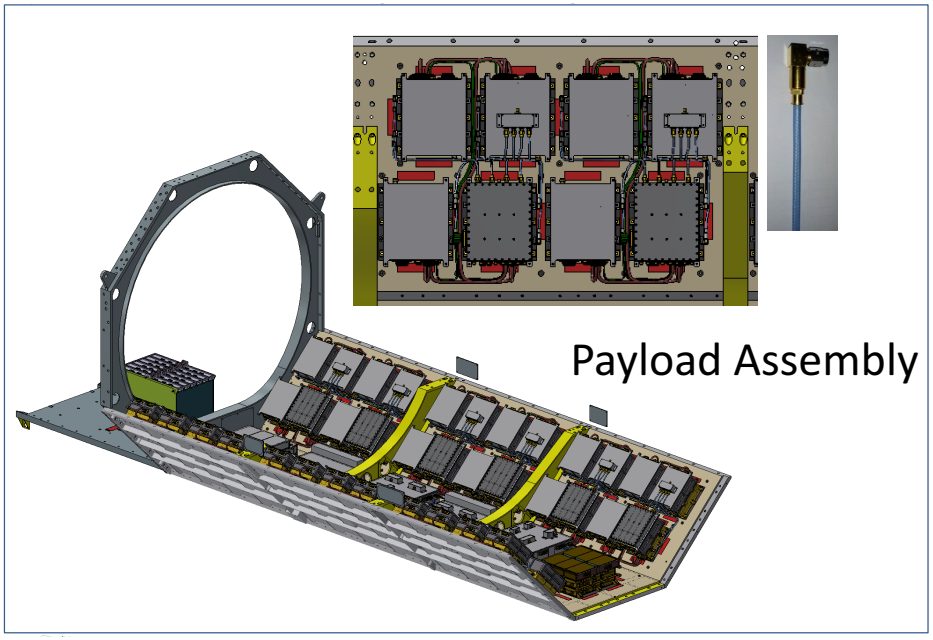


DABF – 12 ADC Card



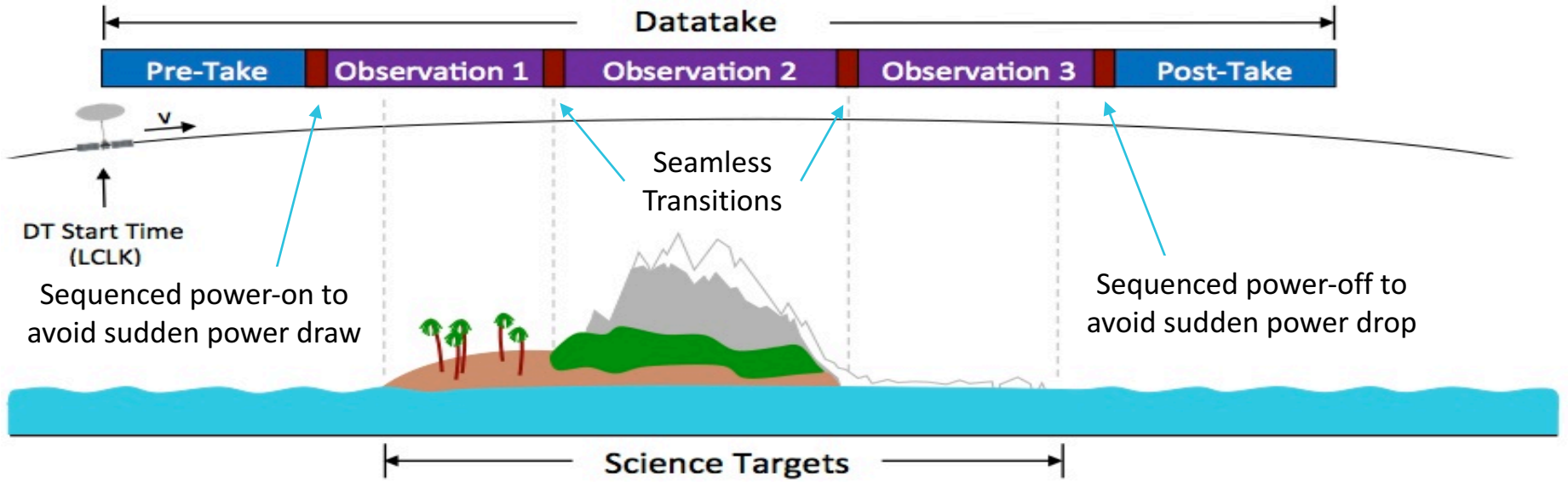
TRC – Part of TRiM

Digital Hardware



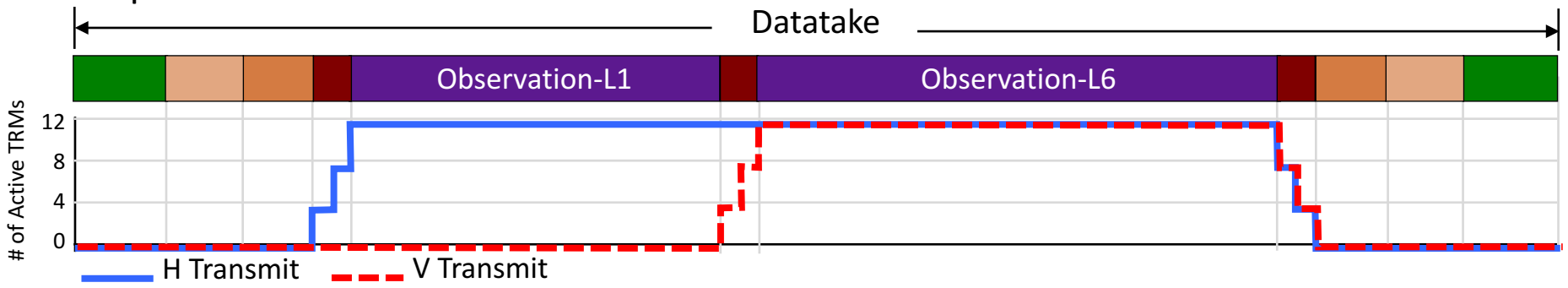
How the L- and S-band radars coordinate observations

- The L-band and S-band radars uses a set of upload-able tables to control radar operations
- Consecutive ***Observations*** with the same start time are grouped into a ***Datatake*** and collected back-to-back with seamless transitions between them
- Each Datatake has a Pre- and Post-take for calibration and at least one or more observations



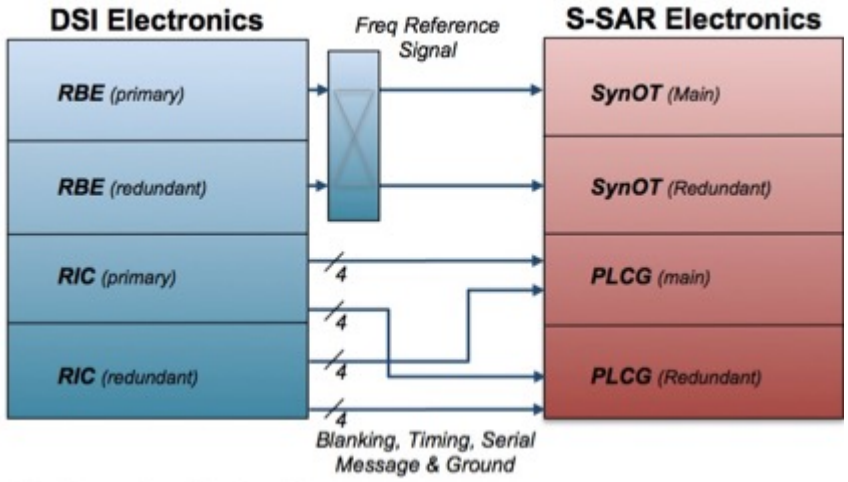
How the L- and S-band radars coordinate timing

- **Joint Data Take Timing Synchronization**
  - To avoid mutual interference during joint operations, transmit events are synchronized
  - L-SAR generates a Timing Reference Pulse and a Global Blanking Pulse and forwards them to the S-SAR electronics to ensure that the transmit events occur in sync
  - L-SAR transmits a digital message to the S-SAR to indicate pulse count, radar clock time, and other parameters to help align the operations of the two radars
  - S-SAR uses the L-SAR STALO and timing signals to derive its pulse timing signals
- **Datatake Power Sequencing**
  - Because of power system constraints, the transitions from idle to transmit and transmit to idle must be sequenced on to prevent transients on the bus
  - S-SAR also does power sequence, but offset from L-SAR to minimize transients on the power bus



L-SAR / S-SAR electrical interfaces are simple and robust

- To ensure proper timing during joint radar operations, four signals are generated by the L-SAR radar electronics and provided to S-SAR. These signals consist of:
  - **Frequency Reference**: 10 MHz StaLO RF signal to derive timing signals (50ohm coax)
  - **Global Blanking Pulse**: Pulsed RS422 signal to synchronize transmit events
  - **Radar Timing Reference**: Pulsed RS422 to serve as a precise time marker
  - **Radar Serial Message**: Asynchronous serial message containing radar mode, L-SAR clock time, L-SAR pulse count, GPS time and position, etc.
- S-SAR uses L-SAR StaLO and timing signals to derive its pulse timing signals for any datatake that contains at least one joint observation



ISRO Science and Applications Objectives

1. **Ecosystem Structure:** 1.1 Agriculture Biomass & Crop Monitoring; 1.2 Forest Biomass; 1.3 Biomass Change; 1.4 Mangroves / Wetlands; 1.5 Alpine Vegetation; #Vegetation Phenology and Vulnerability; #Vegetation soil moisture; #Ecosystem stress assessment.

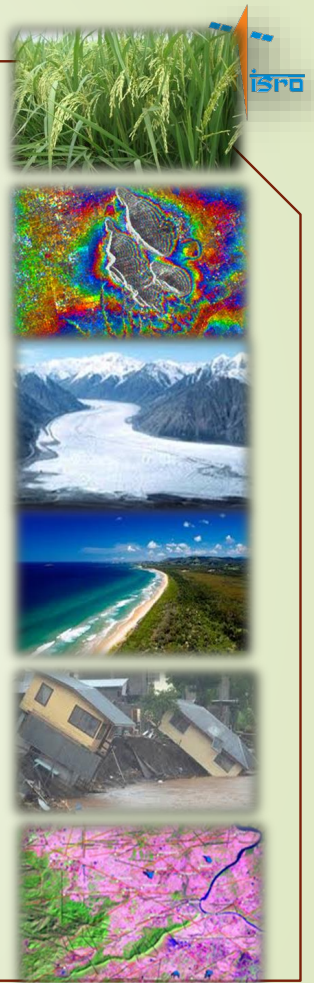
2. **Land Surface Deformation**: 2.1 Inter-seismic / Co-seismic Deformations; 2.2 Landslides; 2.3 Land Subsidence; 2.4 Volcanic Deformations

3. **Cryosphere:** 3.1 Polar Ice Shelf / Ice sheet; 3.2 Sea Ice Dynamics; 3.3 Mountain Snow/ Glacier 3.4 Glacier Dynamics (Himalayan Region); #Glacier hazards; #Climate response to glaciers; #Advisory on safer marine navigation and sea ice.

4. **Coastal Studies & Oceanography:** 4.1 Coastal erosion / shoreline change; 4.2 Coastal subsidence and vulnerability to sea-level rise; 4.3 Coastal bathymetry; 4.4 Ocean surface wind; 4.5 Ocean wave spectra; 4.6 Ship detection; #Possible use of SAR for tropical cyclone; #Coastal watch services

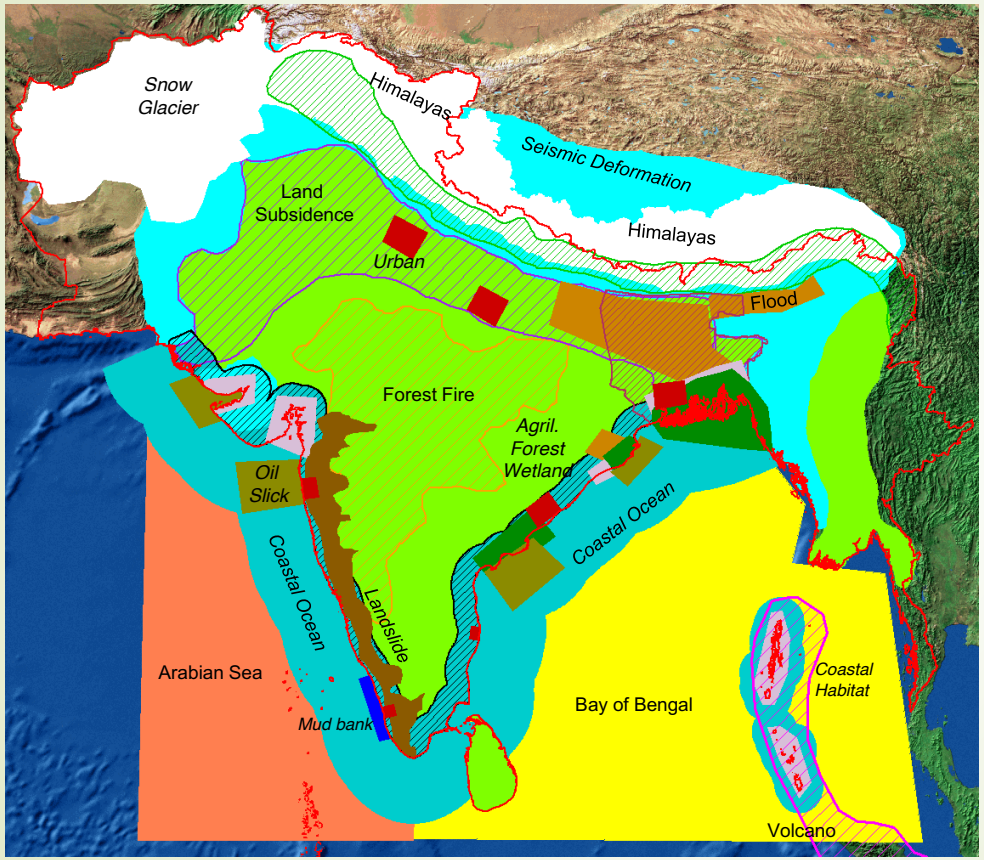
5. **Disaster Response:** 5.1 Floods; 5.2 Forest Fire; 5.3 Oil Spill; 5.4 Earthquakes / Others

6. **Geological Applications:** 6.1 Structural & Lithological mapping; 6.2 Lineament mapping; 6.3 Paleo-Channel study; 6.4 Geomorphology; #Land degradation mapping; #Geo-archaeology; #Mineral explorations



ISRO Targets over India and Surroundings

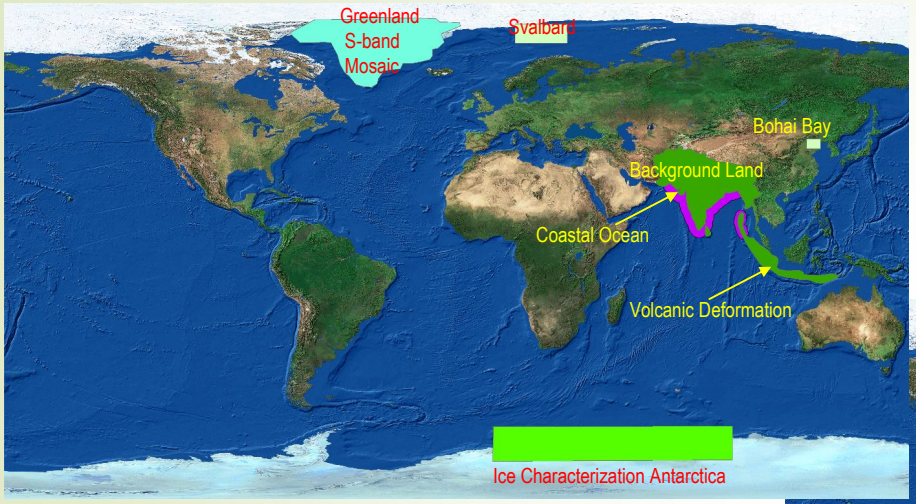
These exclude polar targets



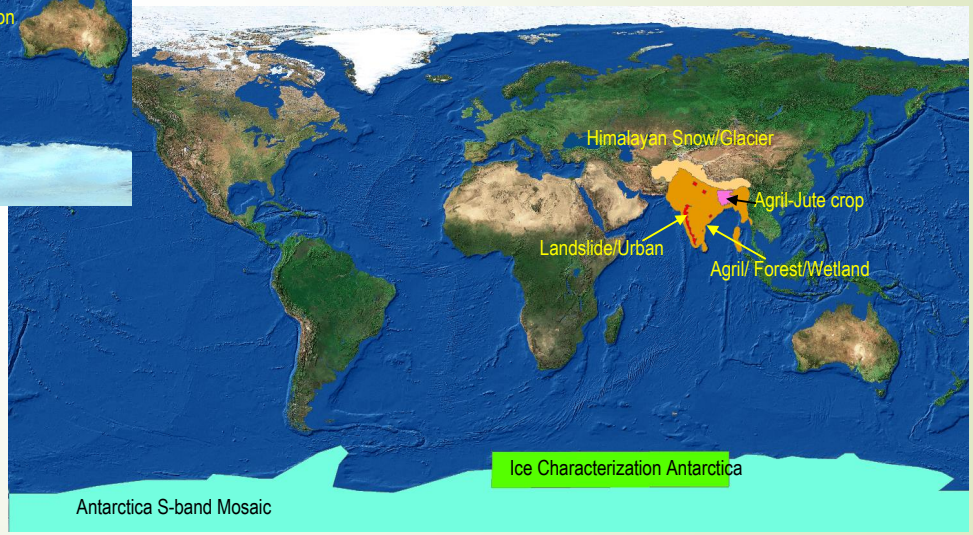
- India + neighbors boundary
- Agriculture/ Forest/ wetland
- Jute crop
- Alpine forest
- Seismic Deformation
- Land Subsidence
- Landslide
- Urban subsidence
- Volcanic deformation/ studies
- Coastal region (sea 300km)
- Coastal habitat
- Coastal deformation
- Coastal mud bank
- Coastal region (land, 100 km)
- Ocean – Arabian Sea
- Ocean – Bay of Bengal
- Disaster – floods
- Disaster – forest fire
- Disaster – oil slick
- Cryosphere - Himalayas

Node-dependent Observation Scheme for Joint Modes

Targets for Descending Node



Targets for Ascending Node



Background Land/ Volc. Deform subsidence/ coastal area
S (DP/CP) 37.5/25 MHz;
L (DP) 20+5 MHz

High Resolution Urban/ Landslide
S (SP) 75MHz; L(DP) 40+5 MHz

Indian Coastal Ocean
S (DP-VV+HV) 10 MHz
L(SP) 5 MHz

Agriculture, Forest & Wetland Himalayan Cryosphere/ Natural Disaster
S (CP) 25 MHz; L (QP) 40+5 MHz

Ice Characterization (svalbard, bohai, antarctica)
S (CP) 25 MHz ; L(VV+VH) 20+5 MHz

S-band Antarctica & Greenland Mosaic
S (CP) 25 MHz

Benefits of Dual Frequency Radar

As demonstrated by the NASA Shuttle Imaging Radar-C in 1994:

- Use of S-band in polar regions could reduce the impact of the ionosphere, since the S-band signal will be 5 times less sensitive than L-band to ionospheric perturbations.
- Use of L-band and S-band jointly would
  - allow an improved estimate of the ionosphere using dual-band mitigation techniques.
  - extend the range of sensitivity for biomass estimation and surface deformation, and aid in estimating soil moisture.
  - improve classification of natural surfaces
  - Improve the utility of interferometry for change detection, and change classification
- S-band instrument has greater coverage capacity than planned
  - Mission trades will determine best balance between L and S-band observations

Example of SIR-C/X-SAR Dual-band Observations (L-band and C-band)

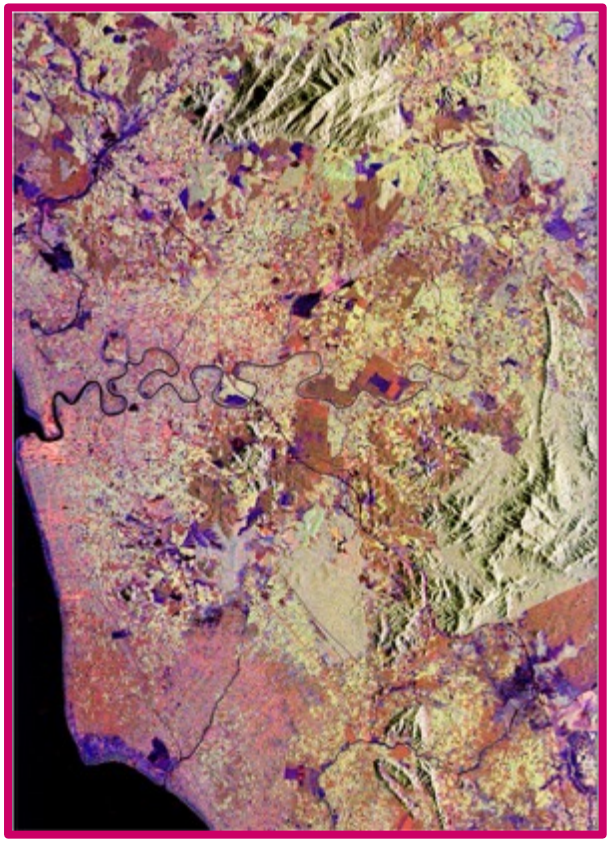
Wheat Fields,

Dnieper River, Ukraine

Red: LHH
Green: LHV
Blue: CHV

Rubber, banana, and oil palm trees,

Muar, Malaysia



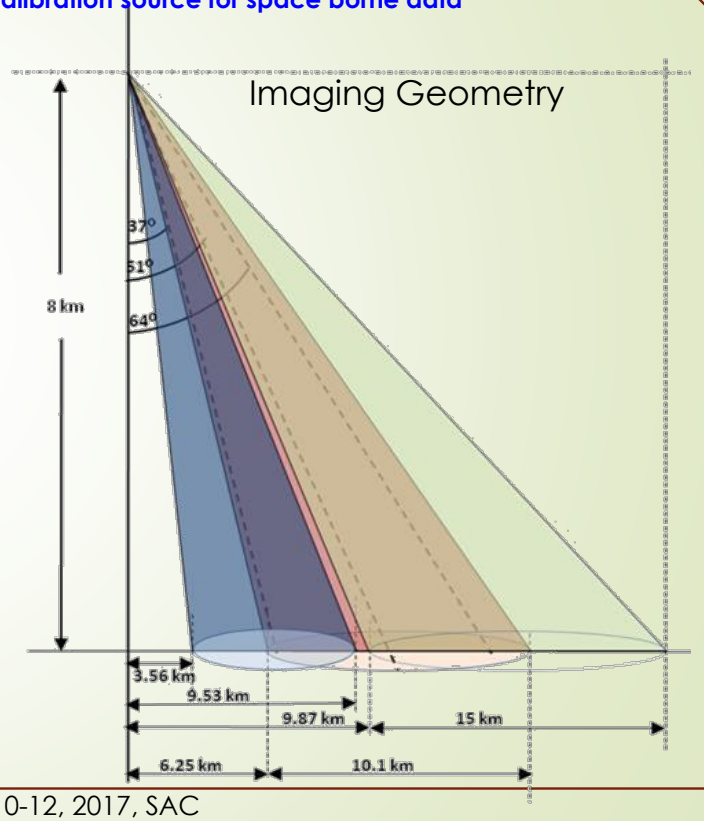
- *The extent to which L- and S- band convey different information has not been extensively studied*
- *ISRO is exploring the phenomenology with an airborne demonstrator*

Development of ISRO L&S band Airborne SAR

- Demonstrate and Verify New Hardware Systems to be used in NISAR – S-SAR
- Deliver NISAR analogue (dual frequency L+S) products to science community
- Various tools development and Data Formatter Verification
- Compare airborne to space-borne SAR for evaluating utility of airborne data as a calibration source for space borne data

System Specifications

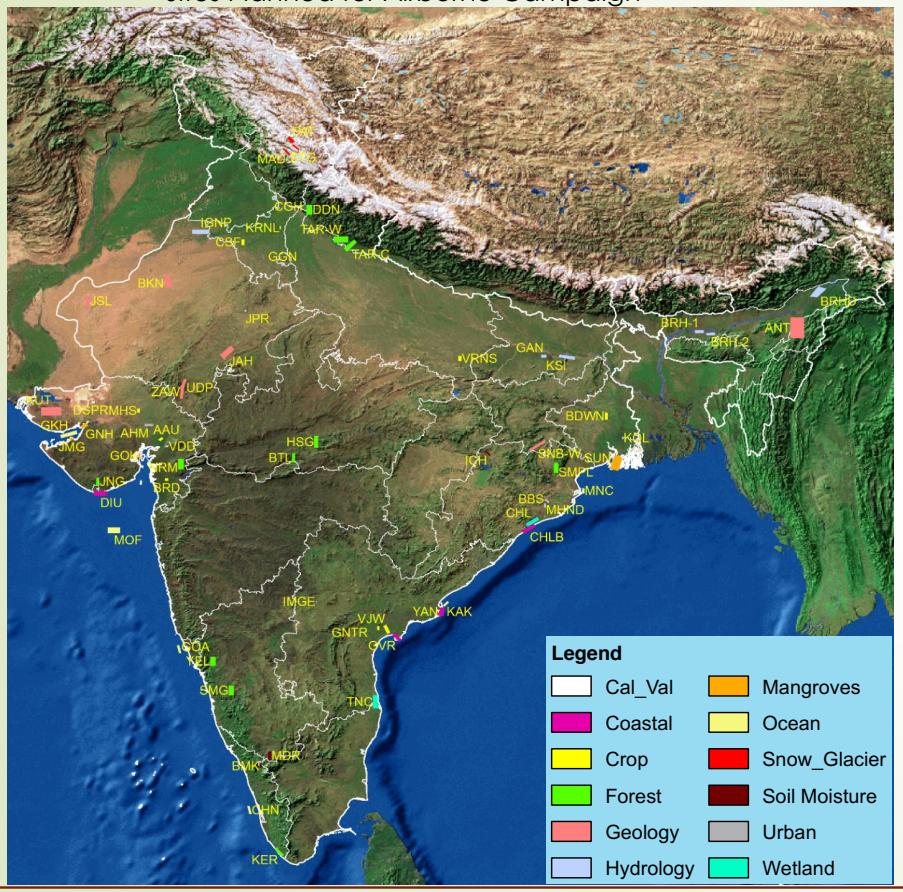
S.No	Parameter	Specification		
1	Platform	Beach craft B-200		
2	Nominal Altitude (kms)	8.0		
3	Nominal Velocity (m/s)	120		
4	Operating Frequency (MHz)	1250 (L) & 3200 (S)		
5	Chirp Bandwidth (MHz)	25	50	75
6	Resolution (m) (Azimuth X Slant Range)	2 X 6	2 X 3	2 X 2
7	Sampling Frequency (MHz)	83.33		
8	SAR Mode	Stripmap		
9	Polarization Modes	Single/Dual/Compact(CP)/Quasi-Quad/Full		
10	Antenna Configuration	Co-Located Antenna		
11	Antenna Polarization	Linear Dual		
12	Antenna dimensions (m)	1.2 (Az) x 0.35 (Ele)		
13	Antenna Roll Bias	37°, 51° and 64°		
14	Look Angle	24° to 77°		
15	Imaging Swath (Nominal)	Overlapped Swath (S+L) 5.5km @37°,9.5km @ 51°,14.5km@ 64°		
16	Integrated Ambiguities	<-20dB		
17	Sigma Naught Threshold	<-20dB		
18	Radiometric Resolution	3dB-Single Look		
19	RF Power Transmit (W)	40 (L) & 165 (S)		



l 10-12, 2017, SAC

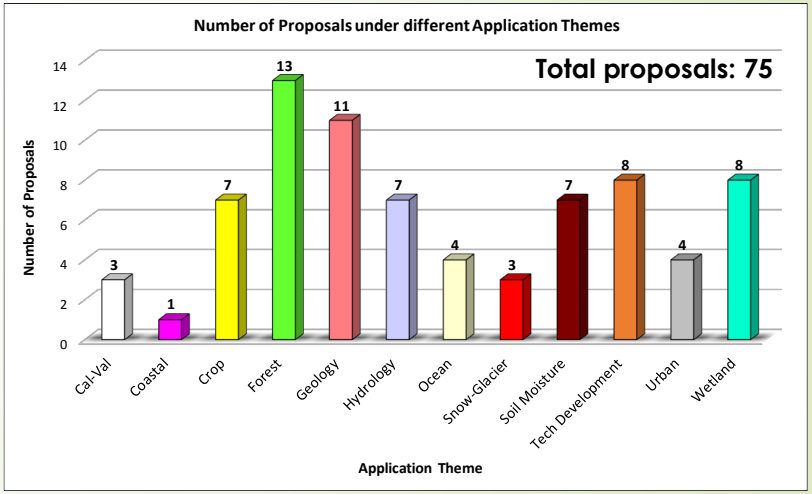
ISRO L&S band Airborne SAR Campaign

Sites Planned for Airborne Campaign



Summary of Project Proposals submitted under A.O

Total proposals submitted: 93
Total proposals accepted: 75



Conclusion

- NISAR is currently in “development” phase (C)
  - Key electronics fabricated to EM level
  - Major procurements executed
  - L- and S-band SAR instruments are being built for joint operations
- Joint L&S band SAR observations planned over extensive areas surrounding India, Indonesia, and the polar regions,
  - Serving as a natural laboratory for dual-band phenomenology and science
- ISRO Airborne L&S band SAR will provide science community with an multidisciplinary science data set to prepare for NISAR
  - First flights in June 2017 – preliminary results demonstrate functionality and show some interesting phenomenological frequency-dependent effects
- Discussions within the joint science team for conducting a joint campaign with UAVSAR in India in 2019

Backup